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GREENPEACE

EDF suffocated by nuclear power

A study of the outlook for EDF's nuclear operations in France

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Contents

1. General background

A. An energy market undergoing far-reaching changes

- **A market in overcapacity related to the development of renewable energy sources**

Before the Fukushima accident, concerns about climate change, energy independence and high fuel prices kick-started a drive in the entire energy sector to move towards renewable energy. The Japanese nuclear accident triggered an acceleration of this movement.

From less than 5 GW in 2010 in France, the available capacity generated by solar and wind power currently accounts for more than 16 GW and the electricity transmission system operator (RTE) predicts that this figure will increase to more than 28 GW in 2021[1].

On 15 May 2016, Germany even succeeded in meeting 100% of the electricity demand from renewable energy sources. Admittedly, this was a Sunday, the day for which demand is conventionally lowest, and yet this achievement demonstrates the extent to which what seemed a utopia a few years ago, can become a reality today.

In addition, the increasing efficiency of renewable energy sources makes them highly competitive today. A report by Bloomberg New Energy Finance (BNEF) in 2015 revealed that wind power had become the more inexpensive energy generated in Germany and the United Kingdom (based on the Levelized Cost of Electricity (LCOE) model or CCE for Coûts Courants Economiques). This calculation does not factor in any subsidies. The analysis of LCOE[2], as used by the French Court of Auditors, also shows that the generation costs for onshore wind and major ground-based solar power plants are now competitive in comparison to conventional energy sources. By means of example, the cost per MWh generated by ground-based solar power in the most competitive plants in operation in 2016/2017 is €70 in France and onshore wind power provides one MWh at between €65 and €85. This cost can be compared to the prices for the future EPRs at Hinkley Point C in the United Kingdom, where the prices per MWh are estimated at around €112, and are inflation-linked.

Furthermore, renewable energy sources have an additional competitive edge due to their drawing priority. They are used before any other available energy thanks to their very low (near zero) marginal cost.

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[1] RTE- *Bilan prévisionnel de l'équilibre offre-demande d'électricité en France (Generation adequacy report on the electricity supply-demand balance in France)* - 2016 Edition

[2] "This method thereby defines an average overall cost over the entire lifetime of generation facilities, which is useful when comparing energy prices." French Court of Auditors (Cour des comptes)

- **Sluggish demand on a downward trend**

2016 has been a major turning point for electricity consumption in France.
Following years of stability, RTE is, for the first time, planning a reduction in French electricity consumption. From 479 TWh in 2015, the electricity transmission system operator predicts that national consumption will drop to 471 TWh in 2021. This trend stems mainly from the increase in energy efficiency measures, "placing projected electricity consumption on a downward trend, despite strong demographics, economic recovery and a favourable situation for new electricity uses."[3]
In its baseline scenario, RTE predicts a 1.5% decline in national electricity consumption in mainland France between 2015 and 2021.

- **Limited scope for exports**

EDF cannot count on its European neighbours' growth drivers either.
The outlook for consumption is also on a downward trend in these countries. Again, the effect of energy efficiency measures has a more significant impact than economic recovery. RTE's baseline scenario estimates a 0.36% drop in the average growth rate for European electricity consumption over the period from 2015 to 2021.[4]
The development of interconnection points will naturally bring about increased exchanges between France and its neighbours, though these exchanges will not allow EDF to improve their profitability to any significant degree as the installed capacity on interconnection points is restricted to a few GW per country.

- **A low price environment**

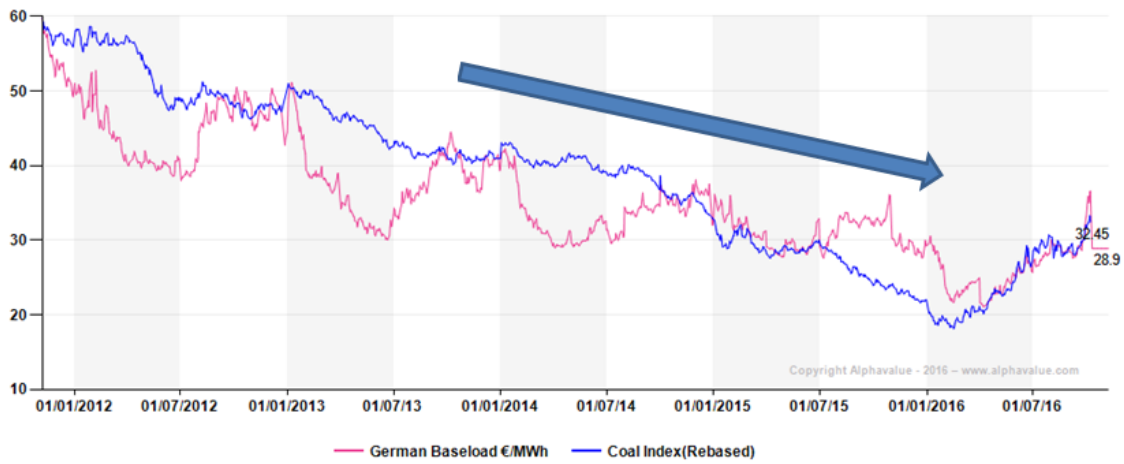
With sluggish demand and renewable energy capacity increasing more quickly than the closure of conventional plants, the European electricity market is in overcapacity and market prices are falling. This phenomenon is heightened by the constant price decline for the raw materials used for electricity generation, such as coal.

In January 2016, the baseload electricity price in Germany was even lower than the prices recorded in the summer of 2015. However, these prices have recently risen following measures to reduce the supply of coal taken by the Chinese government to stabilise the market. The recent doubts on nuclear electricity generation and supply security in France over the winter of 2016/2017 resulted in more speculation on the wholesale markets and a second significant hike in European electricity prices (spot price for Germany €54/MWh and €125/MWh for France).

[3] RTE- *Bilan prévisionnel de l'équilibre offre-demande d'électricité en France (Generation adequacy report on the electricity supply-demand balance in France)* - 2016 Edition
[4] Ibid

We do believe, however, that this is a short-term trend and that electricity prices will return to their low price range in the medium-term. This trend is confirmed by future contracts, which are being negotiated at lower prices for coming years: for 2017 (Cal-17: €33.8/MWh), 2018 (Cal-18: €29.85/MWh), and 2019 (Cal-19: €29.15/MWh).

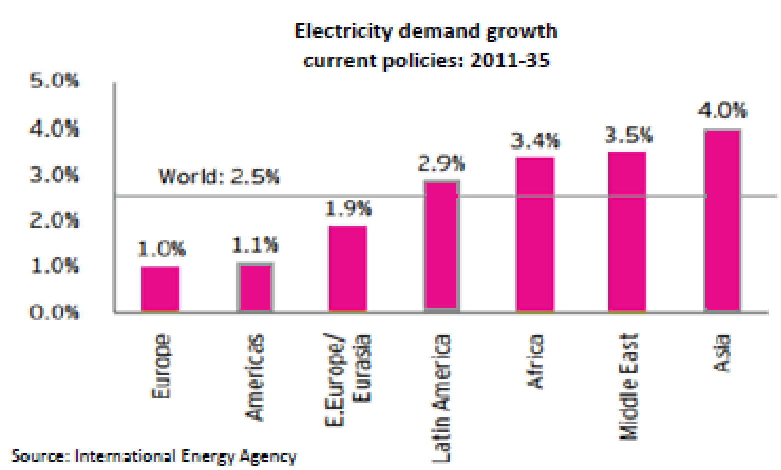
Performance over 5 years: German electricity price (proxy) vs coal



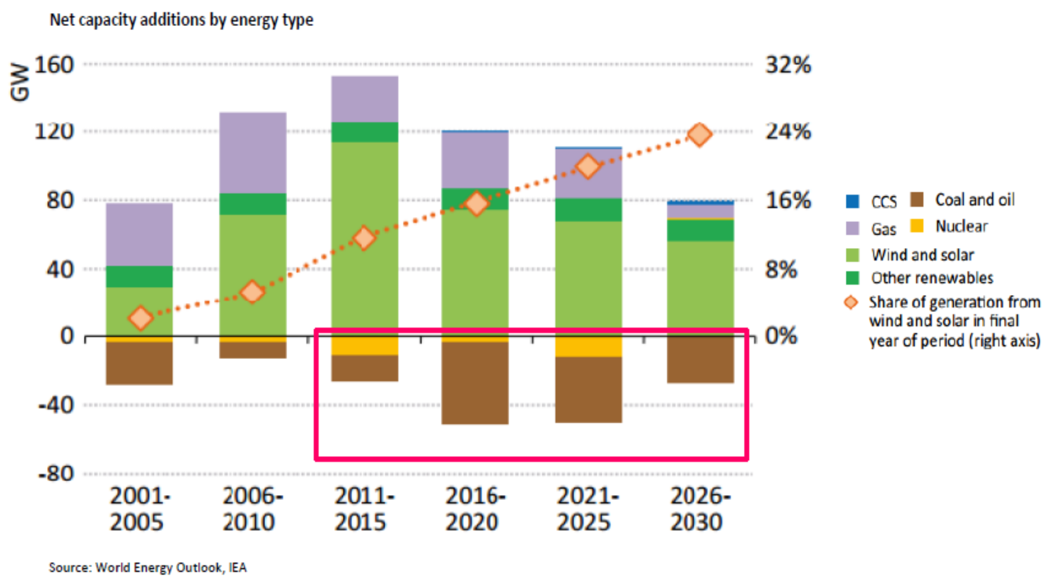
B. A difficult equation for the European nuclear sector

➢ Electricity in developed countries, a mature market

The European market is a mature one. It is in overcapacity and demand trends do not indicate any kind of upturn.
Growth drivers are now outside the European borders, as the figure below demonstrates:



Today, a great majority of new projects concern the development of renewable energy sources.



➢ **The nuclear sector: an economic model poorly suited to the new game plan**

The nuclear sector is highly capital intensive. Its high fixed-cost structure prevents it from developing in line with the constantly-changing market.

The all-nuclear model is no longer valid today:

- Safety requirements are increasing,
- Operating costs are constantly on the rise,
- The competitive edge of nuclear power is quickly losing out to renewables,
- There is an inability to offset rapidly the instant discrepancies between renewable energy generation and demand: nuclear power is unable to provide a rapid response to consumption peaks. This leaves the field open for other conventional energy sources such as natural gas and coal.
  The Annual Energy Outlook 2015 (IEA) predicts that, in the long-term, natural gas could account for more than 60% of new generation capacity from 2025 to 2040, with renewables covering the remainder.
- Market prices are, on average, lower than generation costs,
- Technological problems slow down the development of new projects and make them more expensive: the Flamanville EPR has already doubled its construction timeframe and tripled its cost (the cost of building was initially estimated at €3.5 billion, a figure that has been revised at €10.5 billion),
- Return on investment is lower than capital expenditure (ROI<Capex)

- **Acceleration of plant shutdowns**

One of the consequences of this undertow, which is game-changing for the electricity market, is that the shutdown of nuclear reactors has been brought forward.
Faced with the considerable investments required to keep their reactors in operation, major energy companies such as E.ON and Vattenfall have, or plan to, bring forward the shutdown of some reactors which have become unprofitable. The investment required to continue operations is now higher than the profitability estimated in coming years. Enel has found an agreement to sell its shares in its nuclear power plant in Slovakia. For the moment, EDF does not seem to be considering any of these strategies.

C. What does the future hold for EDF?

- **The painful shift from a monopoly to a competitive market**

The French State owns around 85% of shares in EDF. From a situation of absolute monopoly, the company has been obliged to gradually open its generation and supply business to competition.

On 31 December 2015, EDF eliminated the yellow and green regulated tariffs for companies which are medium to major consumers of electricity.

Its almost-monopolistic situation, together with favourable regulation, had enabled EDF to enjoy a comfortable economic return.
This situation also resulted in the creation of an ineffective and oversized giant, unable to withstand the adverse winds from the electricity market.

EDF is now a company that is uncompetitive and unable to react swiftly and effectively to fluctuating electricity demands and the shake-up caused by the liberalisation of other European markets for spot prices.

EDF is currently lagging seriously behind in the rapid transformation of the energy market. The increasing costs of its nuclear facilities, together with the obsession of selling reactors with complex and expensive new technologies (with total end costs that are still unknown), weaken the company's position considerably.

- **EDF's generation cost trends are poorly adapted to the current market**

EDF's operating costs have progressed significantly in recent years, in particular due to the heightening of safety measures in the wake of the Fukushima disaster, the ageing of its nuclear facilities, increasingly frequent maintenance work and rising provisions.

In its annual report dated February 2016, the French Court of Auditors stated that nuclear electricity generation costs increased significantly between 2010 and 2013. The assessment conducted in 2013 recorded €59.8/MWh (as against €49.6/MWh). The new EPRs, which are currently unrecorded, should make these estimates rise dramatically.

- **A binding legal framework**

The elimination of the yellow and green regulated tariffs on 31 December 2015, i.e. 32.75% of volumes sold in 2014, is a major risk for EDF. Its high fixed-cost structure and lack of responsiveness expose the group to a significant market share loss, to the benefit of smaller and more adaptable operators.

The French law dated 17 August 2015 on the energy transition to support green growth (the "LTECV" law) provides that the national energy policy requires a target of "reducing the share of nuclear power in its total electricity generation to 50% by 2025" (article L.100-4 of the French Energy Code).
Only a considerable rise in demand would allow EDF to leave the number of its reactors in operation unchanged, which, as we have seen, does not correspond at all to the trend observed. The most probable scenario is therefore the shutdown of 17 to 20 reactors, according to the French Court of Auditors. Our estimates allow for the shutdown of 14 to 20 reactors.

2. The valuation of EDF's assets

A. Depreciation of assets

In light of the significant changes in the electricity market's economic landscape, we feel it is important to provide a critical appraisal of the valuation of EDF's generation assets.

We have considered the changes to the growth outlook and have set the value of assets based on the recoverable amount of all Cash-Generating Units (CGU). These units are calculated from estimated discounted cash flows. At the end of 2015, market data continued to influence the profitability of generation assets following changes to long-term scenarios, thus confirming the sustained tensions on Europe's energy market (price decline, drop in demand and overcapacity in electricity generation). The recoverable amount of assets is highly sensitive to CGU growth projections.

B. Significant variations in estimated growth rates per country

Most European energy companies have now drastically adjusted downwards their growth projections for the next few years.

In Germany, for example, the rate used to test the recoverable value of energy generation assets is based on a **0% growth rate** and a weighted average cost of capital (WACC) between 5.2% and 6.4%[5]. This measure has resulted in a significant depreciation of assets and a considerable loss of value for German operators, with depreciations of €3.134 million for E.On and €3.110 million for RWE in 2015.

In contrast, EDF has tested its foreign thermal power assets against several risks and measured the resulting impacts on the CGUs. However, despite tight market conditions, **projected growth remains between 1.7% and 2%** and WACC is 5.9% for Germany and between 6.4% and 10.2% for other European countries[6]. The main purpose of these assumptions, which we consider highly optimistic, is to assess the potential impact on the CGUs of effects such as falling electricity prices, a drop in spreads or changes to the return on assets model.

Conversely, **the thermal and nuclear generation assets of EDF France have not been tested.** This means that the impact of the sustained tensions observed on the electricity market on the long-term profitability of operations in France has not yet been measured.

Conventionally, the recoverable value of each asset represents sensitive data for the company and is not generally disclosed due to its connection to potential future transactions.
Their balance sheet value may be affected by various parameters such as operational lifetimes, the technology used and, of course, its sale price if a sale is considered.
The value of assets entered on the balance sheet is therefore not very clear. However, by cross-checking data obtained from various energy companies with comparable assets, it is possible to identify a general trend in the depreciation of assets conducted and the estimated value of their CGUs. By this means, it is possible to obtain orders of magnitude which can in turn be used to make comparisons between companies.

C. Significant variations between companies

E.On has significantly depreciated the value of its generation assets to take the new price environment into account, by €3.11 billion in 2015 and €3.8 billion in 2016.
Some of its assets are now accounted for at very low values, as a result of the acknowledgement of the zero growth rate in the conventional generation sector.
In general, the expected closure of all German nuclear reactors by 2022 has triggered a considerable decline in their balance sheet value. The company has told us that it has adopted

[5] 2015 annual report, E.On
[6] 2015 reference document, EDF

the assumption of recoverable value of approximately €400 million, which represents a value of **€89.4K/MW** (E.ON's nuclear capacity in Germany is 4.47GW[7]).

RWE does not make comparisons per technology but rather per country. In the UK, for example, where all assets are thermal power facilities, the company has adopted a balance sheet value for its assets of €1.9 billion for an installed capacity of 8.58GW[8], i.e. **€221.4K/MW**. In Germany, the recoverable value of its assets is €6.1 billion, for an installed capacity of 26.49GW, i.e. **€230.2K/MW**. However, this overall value includes thermal power and hydroelectric assets and shares in some nuclear reactors. These figures are not as clear due to this.

Engie has devalued its assets by €8,547M in 2015: €4,160M from the Global Gas & LNG branch, €3,457M from Energie International and €883M from Energie Europe.
As regards its electricity generation assets, €1,111M is related to the fair value less costs to sell in the USA, €1,009M for a power plant in Asia-Pacific (value in use – DCF: 7.8%), €713M for a thermal power plant in India (value in use – DCF: 11.85%), €151M for a thermal power plant in the UK (value in use – DCF: 6.4%), €103M for a thermal power plant in Poland (value in use – DCF: 8.6%), and €91M for a thermal power plant in Spain (value in use – DCF: 7.7%)[9].

As regards the sale of thermal power plants in the USA, the transaction covers 31 plants with a total net capacity of 9.9GW (and two gas transmission assets). It has a net debt impact of €4.1billion and generated a loss of value of €1,111M (the accounting value of the assets exceeded the sale price) of which €911M were allocated to the goodwill of the portfolio.
No other information has been disclosed on the recoverable value of electricity generation assets besides these details on impairments conducted.

D. EDF's asset depreciation situation

In 2015, to take into account the decline in cash generated by the CGUs, EDF allocated an impairment loss of €3.47 billion to intangible assets and property, plant and equipment, which can be broken down as follows:

- €1,096 million in the United Kingdom due to a decline in spreads and a downward revision of capacity premium assumptions,
- €1,419 million in Italy which can be explained by falling electricity and commodity prices (in particular oil prices),
- €186 million in Poland due to the decline in clean dark spreads,
- €198 million in Belgium following a change of model for return on assets,
- €117 million in Germany related to the decline in seasonal spreads and volatility,

[7] 2015 annual report, E.ON
[8] 2015 annual report, RWE
[9] 2015 reference document, Engie

- €107 million for EDF Energies Nouvelles (outside of France) due to the increased country risk in Greece and poor performance in some activities,
- €343 million following the termination of some renewable projects in France and in the USA.

By studying the little information provided by EDF, a net balance sheet value for its conventional electricity generation assets excluding nuclear power (mainly hydroelectric and thermal power) of €8.9 billion can be noted for an installed capacity of 32GW, i.e. a value of €278.2k/MW. The net value of its nuclear assets is assessed at €24.68 billion, for a total installed capacity of 72GW, or a value of €342.7k/MW[10].
Regardless of the basis of the comparison (E.ON, RWE or Engie), the valuation of EDF's assets is therefore significantly greater than that of its peers.

In addition, the rise in renewable energy sources, a drop in the use of nuclear plants (and in conventional energy sources in general), a shorter lifetime for some reactors and a general pressure on electricity prices could lead to projections for a depreciation of nuclear and thermal power assets in France.
The operational lifespan is a decisive factor in asset valuation. Yet the current economic environment does not provide the necessary guarantees for a sufficient return on investment to implement the maintenance work and enhanced security requirements, which are essential to obtain an authorisation to continue operations granted by the French Nuclear Safety Authority (Autorité de Sûreté Nucléaire - ASN).

The case in Sweden is a very telling example: Swedish operator Vattenfall recently decided to shut down two nuclear reactors (Ringhals 1 and 2,) eight and ten years prior to the end of their operating permits, as the projected return on investment is now lower than the investment required to comply with the post-Fukushima safety requirements.
The significant drop in profitability of its plants caused by lower electricity prices and increased operating costs were also factors in the company's decision.
This decision generated an impairment loss for its nuclear assets of approximately €2.45 billion (SEK 23.8 billion) in 2015[11].

This scenario could be easily considered for EDF.
The balance sheet risk is even greater as its generation assets in France (mainly nuclear) are very probably overvalued. An impairment loss would automatically result in an adverse impact on equity. The risk is substantial, however, as we lack detailed data, we can only mention it.

[10] 2015 reference document, EDF
[11] 2015 annual report, Vattenfall

3. Decommissioning and waste management of French reactors

A. Background

Nuclear reactor operators are obliged to establish provisions to cover the cost of dismantling their nuclear facilities and of managing the resulting waste, and to allocate the necessary assets to cover these provisions exclusively[12].

With the ageing of reactors – most of which were built in the 1970s and 1980s – and the development of new energy sources, the question of their dismantling is becoming increasingly pressing. It is therefore urgent that nuclear operators put aside sufficient amounts to manage the situation.

Very few decommissioning operations have been finalised to date. There is therefore a lack of feedback and the cost of the various operations has been the subject of many discussions.
In addition, the comparability of operations according to reactor type, lifespan and technology used, etc., is regularly challenged.
It is therefore particularly difficult to assess decommissioning and waste management costs.

In their balance sheets, energy companies enter the discounted value of future expenditure resulting from their nuclear operations as provisions.

There are two types of provisions:

- Provisions for reactor decommissioning (which also include losses in relation to unused fuel loaded in the reactor: the last core),
- Provisions for "downstream" operations, which include the cost of managing waste produced throughout reactors' lifecycles.

Discounting, used to calculate these provisions, considers various parameters, assessed in different ways by each operator and according to the regulations in force:

- An inflation rate which will take the evolution of costs into account until the day of expenditure,
- A discount rate which is calculated from the projected return on capital rate until expenditure,
- A discounting timeframe between today's date and the date of expenditure.

Let us take the example of inflation rates to demonstrate these differences:

Germans believe that decommissioning and waste management costs evolve more quickly than economic inflation. They will therefore select an inflation rate in line with their projection.

The energy companies EON and RWE have used inflation rates of 3.7% and 3.6% respectively while EDF uses a rate of 1.5%.

[12] Code de l'environnement- articles L.594-1, L.594-2 et L.542-12

The discounting timeframe is decided in accordance with the remaining operating period of each reactor. This timeframe naturally depends on the age of the reactors and decisions concerning lifespans are generally made by governments.

These processing differences may seem to prevent any comparisons of provisions. However, by incorporating these different parameters into our model, we have nevertheless been able to obtain comparable data.

The comparisons for EDF are conclusive. The group dramatically underfunds the estimated decommissioning and waste management costs for its nuclear facilities (see comparative table on p.15).

B. Underfunded decommissioning costs

With the exception of EDF, very few energy companies state the amount required for the decommissioning of their reactors in terms of current economic conditions.

They state, however, in their financial statements, the discounted value – i.e. the provisions – of this expenditure.

As mentioned above, these amounts are not comparable as they stand.

To overcome this issue, we have used decommissioning provisions to recalculate the amount of the cost in terms of the current economic conditions.

a) Decommissioning provisions accounted for by EDF

In order to assess the cost of decommissioning its French reactors, EDF separates reactors in operation and reactors which have been shut down.

- For reactors in operation, EDF conducted a study in 2009 of decommissioning costs by using Dampierre (four 900MW units) as a reference site and reviewed the study in 2014. The study breaks down decommissioning into many operations and allocates a cost to each one. The estimated amount is then extrapolated to other reactors.
- The decommissioning costs for reactors already shut down (reactors A1, A2 and A3 at Chinon, A1 and A2 at Saint Laurent, Bugey 1, Chooz A, Brennilis and Creys-Malville, and three ancillary facilities) are assessed using regularly reviewed contractor quotes.

The corresponding costs for all the group's reactors in France, and their discounted value, are stated in the table below:

Table 1

(in millions of Euros)	30/06/16		31/12/15	
	Costs based on economic conditions at 30 June	Amounts in provisions at present value	Costs based on economic conditions at 31 December	Amounts in provisions at present value
Decommissioning provisions for nuclear power plants	26,202	13,685	26,067	14,930
Provisions for last cores	4,283	2,150	4,113	2,555
Decommissioning and last core expenses	30,485	15,835	30,180	17,485

Source: EDF- Consolidated half-year financial statements at 30 June 2016

b) Provision assessment assumptions

For the purposes of this exercise, we have considered the remaining lifespan of each reactor, and the inflation and discounting dates selected by each operator on our panel.

We have adopted the assumption of the French Court of Auditors (Cour des comptes)[13] of a weighted mean point (barycentre) of reactor decommissioning expenditure eight years after the start of decommissioning which must begin as quickly as possible after reactor shutdown.

The German example is quite simple. Following the Fukushima disaster, the government decided to shut down all its nuclear power plants by 2022 at the latest and the shutdown dates for each of these reactors have been announced. The discounting timeframe for future expenditure is therefore easier to calculate.

As regards EDF, the question of reactors lifespans is more uncertain. French reactors were built for an operating period of forty years. This period is, however, subject to the French Nuclear Safety Authority (Autorité de Sûreté Nucléaire - ASN) which may or may not authorise the continued operation of each reactor during its ten-year inspections.

Without waiting for the case-by-case decisions of ASN (which will be issued between 2019 and 2028), EDF decided this year to extend the commercial operating lives to fifty years of its 900MW reactors in France (i.e. 34 reactors).

This decision, which is only an accounting decision to date, does not take into consideration the French energy transition law which limits nuclear electricity generation to 50% in 2025 (as against around 75% today).

Neither does it acknowledge the doubts raised by ASN itself with regard to a possible decision in favour of extending the operating period[14].

[13] Cour des comptes (French Court of Auditors) – *The costs of the nuclear power sector* – January 2012
[14] ASN – Revue technique de la sûreté nucléaire et de la radioprotection- n°198, November 2014 (in French)

ASN's President, Pierre-Franck Chevet, commented before the French National Assembly on 13 February 2014[15]: "Subject to an inspection of each reactor, we agree with the principle of extending operation up to forty years, but not up to fifty or sixty years. In this case, it is not simply subject to inspection. Major technical obstacles are still to be overcome".

ASN will only issue its decision with regard to a generic framework in 2018 and on the first reactor to reach its fourth ten-year inspection in 2019 – reactor number 1 at Tricastin. Only then will the ASM specify the safety baseline and the requirements to be applied in order to obtain an authorisation for extended operations.

We have therefore adopted the assumption that EDF will shut down 17 reactors in France by 2025 (this figure is explained on page 24 of this study and set out in more detail in the appendix). These 17 reactors account for half of those which will reach their forty years of operation before 2025.

In conclusion, we have opted to include the decommissioning of reactors 2 and 3 of San Onofre in the USA in our comparison because the cost of these operations is particularly well documented.

c) Comparative table and comments

The following table is a summary of our calculation results:

Table 2: Comparison of reactor decommissioning provisions

	EDF France (1) 2016	EDF France (2) 2016	ENGIE 2015	E.ON 2015	RWE 2015	San Onofre 2&3
Installed capacity (GW)	67.340	67.340	5.888	8.271	6.308	2.150
Cost based on the present economic conditions (€bn)	30.485	30.485	5.622	8.374	5.268	3.135
Cost /GW (€M)	***452.7***	***452.7***	***954.9***	***1 012.4***	***835.1***	***1 458.2***
Average costs/GW (€M)	942.7	942.7	942.7	942.7	942.7	942.7
Deviation vs average cost/GW (€M)	***- 489.9***	***- 489.9***	***12.2***	***69.8***	***- 107.5***	***515.5***
Adjusted cost based on the present economic conditions (€bn)	63.5	63.5	5.6	7.8	5.9	2.0
Adjusted provisions (€bn)	36.7	35.1	3.6	7.3	5.5	Unreported
Provisions recorded on the balance sheet (€bn)	15.8	15.8	3.6	7.9	4.9	Unreported
Provision deviation (€bn)	***20.9***	***19.2***	***0.0***	***-0.5***	***0.6***	Unreported

Source: Alphavalue

[15] http://www.assemblee-nationale.fr/14/cr-cenucleaire/13-14/c1314016.asp (in French)

(1): 17 reactors are to be shut down by 2025 in compliance with the LTECV law target of 50% of electricity generation from nuclear power
(2): The two reactors at Fessenheim are to be shut down by 2025 in compliance with the 63GW nuclear electricity generation ceiling provided for by the LTECV law

We have considered that the cost/GW, obtained by calculating an average of recorded costs, was a benchmark for all operators under study.

As a result, Engie, RWE and E.ON have correctly calculated their decommissioning provisions in relation to the average cost.

However, according to these calculations, the provisions approved to cover the cost of financing the decommissioning of French reactors is far from sufficient.

In the scenario that 17 reactors are shut down by 2025, EDF would have to increase the amount of its provisions for the decommissioning of French reactors by more than €20bn, and by more than €19bn in the scenario of the 63GW ceiling.

This figure may appear exorbitant, and yet the cost of decommissioning at the economic conditions of 31/12/2015 approved for EDF's reactors in the UK is much greater. EDF assesses the decommissioning cost at €16,997M for an installed capacity of 8,918MW[16], i.e. €1.9bn/GW.

This amount is also much higher than the average costs recorded in our table (€942.7M/GW). The different technology used in these reactors may explain the difference in assessment with PWR reactors. This point must, however, be highlighted.

d) The question of economies of scale

To justify its calculations to estimate decommissioning costs, which are significantly lower than those of its peers, EDF argues in particular "the series effect that can be reasonably expected from the decommissioning of the PWR fleet"[17]. The size of the fleet in operation (58 reactors) and its standardisation (PWR technology) should indeed enable the group to benefit from economies of scale when the time comes for decommissioning.

To take into account this effect, we have made a conservative assessment of the economy of scale of €100K/installed MW. This figure reflects an average reduction of approximately 10.5% which will be more apparent in the last operations conducted in view of the investments already made (facilities, installations, equipment) and expertise gained on-site. Given that the installed capacity of PWR reactors is 63,130MW, the overall **economy of scale** would be **€6.3bn.**

The corresponding provisions would then represent €31.6bn if the 900MW reactors (with the exception of Fessenheim) are all extended and €33bn if EDF must shut down 17 reactors.

[16] EDF 2015 Reference Document
[17] Ibid

The **corresponding underfunding is therefore €15.8bn and €17.2bn respectively**, when these "economies of scale" are factored in.

C. Waste management: a difficult equation

The question of waste management is a key issue. The volume of waste is constantly on the rise and the future shutdowns of reactors and their decommissioning will generate new nuclear waste.

In France, as most reactors will reach their fortieth anniversaries in the next ten years, there is increasing pressure on the capacity of storage centres tasked with receiving this new waste.

At the same time, intermediate- to high-level long-lived waste, according to the number and lifespan of the reactors in operation, is constantly increasing and yet there is currently no long-term storage solution available.

If some countries, such as the USA, plan to build storage units on-site pending the creation of long-term solutions, other countries, such as France and now Germany, are favouring the construction of storage sites in deep geological strata.

Regardless of the solution selected, waste management is the responsibility of nuclear operators and they are obliged to allocate provisions for this in their accounts. It is currently very difficult, however, to obtain a quantitative estimation of such work.

a) Highly uncertain assessments

In its 2014 report[18], the French Court of Auditors (Cour des comptes) stated: "As regards future expenditure end-of-life obligations, waste management is the area with the most uncertainty, which could ultimately result in significant excess costs".

Such uncertainty clearly concerns all types of nuclear waste, regardless of its origin: nuclear facility operations, their decommissioning, the recovery and conditioning of old waste and spent fuel.

However, the greatest uncertainty surrounds the management of the most radioactive waste, known as high-level and intermediate-level long-lived waste (HLW-ILW-LL) for which no solution has been found to date.

Studies cited by the French Court of Auditors (Cour des comptes) in 2012[19], estimated the cost of storing the HLW-ILW-LL generated by a reactor in one year at €20M. For the French fleet, the report gave a total amount of €36bn$_{2010}$ for 1758 reactor-years (the total number of years each reactor is in operation).

[18] Cour des comptes (French Court of Auditors) - *Le coûts de production de l'électricité nucléaire, Actualisation 2014* – May 2014 p.92 (in French)
[19] Cour des comptes (French Court of Auditors) – *The costs of the nuclear power sector* – January 2012

In 2016, ANDRA (the French National Radioactive Waste Management Agency) revised its estimation of the cost of the CIGEO geological waste disposal project in Bure, Meuse. The estimated amount was almost doubled between 2005 and 2010, from less than €20bn to €34.5bn, of which €19.8bn is for site construction (from 2021 to 2025), and €8.8bn for its operation over more than one hundred years (from 2028 to 2156).

The Agency also specified that this estimate excludes "risks and opportunities". Given the project's long lifespan, it is easy to imagine potential excess costs.

ASN issued a positive opinion of this study but considers that some of the technical and economic assumptions made by ANDRA are overly optimistic and therefore not consistent with the prudence that is essential for such an evaluation[20].

To conclude, the French Ministry for Energy, represented by its Minister Ségolène Royal, issued a decision early this year to set the cost at €25bn. This political decision will probably successfully satisfy most of the parties (operators and the regulator).

b) The assumptions adopted by EDF

As with decommissioning, nuclear waste management costs are assessed by EDF directly, under the supervision of an administrative authority, embodied by the French Ministries of the Economy and of Energy.

However, for the CIGEO project, as EDF is the main producer of HLW-ILW-LL in France, its share of financing is estimated to be 78%, i.e. almost €20bn.

The half-year financial statements dated 30/06/2016 indicate a provision for nuclear waste management of €18.4bn.

At this point, let us note a question concerning the discounted amount of the cost of long-term management of radioactive waste.
According to data issued by the French Ministry of Energy, the CIGEO construction costs will be spent over the period from 2021 to 2025. The discounted value of the corresponding cost for EDF (78% of €19.8bn, i.e. 15.4bn) should therefore be very close to its value at current economic conditions. A simple calculation with the discounting rate used by EDF over a nine-year period (2025) - a highly conservative period – results in a discounted value of €12bn. The provision of €8bn recorded by EDF in its half-year accounts, including other costs in addition to CIGEO, is considerably lower.

[20] http://www.french-nuclear-safety.fr/Information/News-releases/Cost-of-the-Cigeo-project-ASN-publishes-its-opinion-on-the-evaluation-proposed-by-Andra

Table 3

(in millions of Euros)	30/06/16	
	Costs based on economic conditions at 30 June	**Amounts in provisions at present value**
Spent fuel management	16,995	10,318
Long-term radioactive waste management	29,203	8,086
BACK-END NUCLEAR CYCLE EXPENSES	46,198	18,404

Source: EDF- Consolidated half-year financial statements at 30 June 2016

c) The German example of waste management applied to EDF

In 2011, just after the Fukushima nuclear disaster, the German government decided to speed up the phasing-out of the 17 reactors still in operation in Germany, so that the country could permanently cease all nuclear generation by 2022 at the latest. Nine reactors have already been shut down, eight others will be shut down by the deadline.

The problem of financing nuclear waste management has therefore become a short-term reality.

The main concern is now to secure funds to avoid passing the burden on to citizens and future generations.

By drawing inspiration from Swiss and Swedish experiences, the government decided to create a public fund dedicated to the financing of radioactive waste management.

The proposed legislation, providing for the financing of the fund by nuclear operator to the tune of €23.5bn, was adopted on 19 October 2016 by the federal government.

This is broken down into a basic amount of €17.4bn together with a "risk surcharge" of €6.2bn for its entire nuclear fleet (in operation or shut down), to cover potential excess costs which are highly likely as there is currently no feedback that can be used to assess the estimated amounts. Operators will have to pay at least 20% of the amount by January 2017. The outstanding amount will be subject to an annual interest rate of 4.58% and must be settled in full by 2022.

Table 4- ***Mandatory deposits required from the operators RWE and E.On for the Nuclear waste disposal fund***[21]

Nuclear power plant	Operator	Technology	Installed capacity Mwe (1)	Basic amount €M (2)	Risk surcharge: 35.47%	Total amount €M	Basic amount /capa (€M/Mwe) (2)/(1)
Unterweser	EON	PWR	1345	1035	367	1402	0.77
Isar 1	EON	BWR	878	668	237	905	0.76
Grafenrheinfeld	EON	PWR	1275	1028	365	1393	0.81
Grohnde	EON	PWR	1360	1063	377	1440	0.78
Brokdorf	EON	PWR	1370	1064	377	1441	0.78
Isar 2	EON	PWR	1400	975	346	1321	0.70
Gundremmingen A	RWE	BWR	237	178	63	241	0.75
Biblis A	RWE	PWR	1167	907	322	1229	0.78
Biblis B	RWE	PWR	1240	980	348	1328	0.79
Gundremmingen B	RWE	BWR	1284	971	344	1315	0.76
Gundremmingen C	RWE	BWR	1288	998	354	1352	0.77
Emsland	RWE	PWR	1329	1124	399	1523	0.85
Total				**10,991**	**3,899**	**14,890**	**0.77**

Source: German federal government, AlphaValue

For E.ON and RWE, the distribution of these provisions estimates the discounted cost of waste processing at €0.77M/MW on average. The risk surcharge of 35.47% required of operators represents an additional amount of €0.28M/MW. In total, nuclear operators will have to pay €1.05M/MW to the fund.

EDF's consolidated financial statements at 30/06/2016 indicate a provision for nuclear waste management of €18,404M for an installed capacity of reactors in operation or shut down of 67,340 MW, i.e. an amount of €0.27M/MW…By means of comparison, this amount barely covers the risk surcharge required of German operators!

To reach the level of financing required of nuclear operators by the government, EDF would have to increase its waste management provisions by €52.5bn: €33.5bn for the basic provision and €19bn for the risk surcharge.

While this amount may seem mind-boggling, it does not take into consideration the much lower quantity of waste produced by German operators in comparison to EDF. Several German reactors have been shut down before their operating permits expired. In 2022, when the last

[21] Gesetzentwurf der Bundesregierung- *Entwurf eines Gesetzes zur Neuordnung der Verantwortung in der kerntechnischen Entsorgung*- October 2016

German reactor will be shut down, the average lifespan of the 17 reactors will be less than 30 years. They will have therefore used less fuel than previously planned.

EDF, however, has just extended the lifespan of 34 of its reactors to 50 years in accounting terms, reducing the annual provision.

d) Accounting impacts

The under-reserved amounts are so considerable that entering them onto the balance sheet would irremediably send EDF into bankruptcy.

To align EDF's waste management provisions with those of the German operators, an impairment charge would have to be applied as early as this year to the tune of €52.5bn (risk surcharge included) or €33.5bn (excluding the risk surcharge).

In addition, the regulation in force obliges EDF to secure these amounts with dedicated assets. The group would therefore have to increase them by a similar amount.

This equation is difficult to sustain for a company with equity (restated from "hybrid" loans) of approximately €25bn.

This operation results in an equity shortage that will be considered later in the study.

4. The cost of future investments

A. The cost of planned investments (with the exception of the Grand Carénage programme)

EDF has made several investment commitments for the next ten years. A summary of these commitments follows:

- The EPRs at Hinkley Point and Flamanville: The cost is estimated at £18 billion, i.e. approximately €22 billion at the current exchange rate. The two new reactors must each be constructed in 6.5 years, between 2018 and 2026. Even though we feel this target is particularly ambitious, given the feedback from Flamanville and Taishan, we have used these assumptions for our calculations.
  If expenditure is also distributed over time, the investment would be €3.385 billion per year, of which €2.25 billion would be for EDF (which must finance 66.5% of the project).
  Prior to the start of construction work at Hinkley Point C, scheduled for 2018, we estimate that EDF will have to invest approximately €1bn per year to complete the EPR, the first of its kind, at Flamanville in France.

- One of EDF's main targets in its CAP 2030 strategic programme is the doubling of global capacity in renewable energy. This requires significant investment in coming years. "EDF has set itself the goal of doubling its net installed capacity from 28GW to 50GW in 2030"[22]. According to the technology used (mainly solar and wind power), the cost of facilities may vary between €1 and €2 million per MW. Considering an average price of €1.5 million per MW, the 22 GW of installed capacity would cost EDF €33 billion, i.e. an average of €2.2 billion per year over fifteen years.

- The electricity grid is one of EDF's core activities. The group must be able to adapt to all kinds of energy sources and to renewables in particular. In order to manage the volatility caused by the use of renewables more effectively, EDF is currently implementing a "smart meters" installation programme (Linky). The installation of these smart meters, maintenance and network operation currently reflect an average investment of €3.35 billion per year.
  We have used this average cost in our future investment assumptions. It is, however, deemed to be particularly conservative, given the additional investments required to modernise the ageing French grid.

- EDF's non-French assets (British nuclear plants, assets in Italy, international investments and the service sector) account for recurring investments within the range of €3.5 and €4 billion per year. We have used an average annual amount of €3.7 billion in our calculations.

- Lastly, the planned takeover of Areva NP (initially estimated at €2.5bn for 100%) is now beset by too much uncertainty for us to assess it successfully. The amount (between €0 and €2.5bn) is "marginal" when compared to other expenditure. For this reason, we will only value this item when the schedule and various investment phases become clearer.

Table 5

€ billions	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
HPC & New Nuclear	1.00	1.00	2.25	2.25	2.25	2.25	2.25	2.25	2.25	2.25
EDF EN	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20
French grid	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35
Other (UK, Italy, Services)	3.70	3.70	3.70	3.70	3.70	3.70	3.70	3.70	3.70	3.70
Total	**10.25**	**10.25**	**11.5**	**11.5**	**11.5**	**11.5**	**11.5**	**11.5**	**11.5**	**11.5**

Source: Alphavalue

[22] https://www.edf.fr/en/the-edf-group/world-s-largest-power-company/strategy

B. The Grand Carénage programme

The Grand Carénage is a specific programme implemented by EDF, the aim of which is the integrated management of all work required for the operation of the French nuclear fleet.

Large-scale renovation and modernisation work is necessary to increase facilities' protection against extreme situations, an obligation since the Fukushima disaster. In addition, as some components reaching thirty years of operation are showing signs of wear and tear, EDF must schedule their replacement. This is the case of steam generators, transformers and alternators.

The total cost of this programme will depend on the number of remaining reactors in operation. In compliance with the French energy transition law, EDF will be obliged to shut down reactors. In addition, the renovation of the fleet and the replacement of some major components may enable the group to obtain the necessary approval for the extension of some reactors beyond forty years of operation. We must remember, however, that despite EDF's decision to extend operations at its 900MW reactors in accounting terms in 2016, ASN alone is empowered to issue an extension authorisation.

Work under the Grand Carénage programme presented by EDF was revalued at the end of 2015 by the group at €51bn over the period from 2014 to 2025 (as against €55bn over the period from 2012 to 2025). This is the timeframe during which the 900MW reactors will reach their forty years of operation and the 1300MW reactors their thirtieth anniversaries. Distributed on a straight-line basis over the period, this assessment represents an annual cost of €4.64bn.

However, the estimations of the French Court of Auditors (Cour des comptes) differ from EDF's figures.

Firstly, the Court considers a longer reference period, of sixteen years (2014-2030). Secondly, it adds operating expenses such as maintenance: "Maintenance operations require not only replacement or major upgrading operations (investments), but also work for general upkeep (maintenance)"[23]. Investment expenditure is estimated at €74.73 billion between 2014 and 2030 and operating expenses at €25.16 billion for the same period. This represents annual investment expenditure of €4.67 billion and maintenance expenditure of €1.57 billion per year. If this budget is calculated for the period considered by EDF (2014-25), this represents an investment of €51.4 billion and maintenance expenditure of €17.3 billion. Both estimations are consistent. The discrepancy lies in the estimation of operating expenses, not taken into account by EDF.

This budget drawn up for the Grand Carénage programme does not specify the number of reactors concerned, or even if EDF is planning to shut down some of them.

[23] Cour des comptes, Rapport publique thématique : *La maintenance des centrales nucléaires : une politique remise à niveau, des incertitudes à lever,* (2016) (in French).

Yet the French energy transition law provides that nuclear electricity generation will be capped at 63.2GW in 2025. The assumption of the commissioning of the Flamanville EPR would therefore result in the shutdown of two 900MW reactors. We therefore believe that the budget is calculated for a nuclear fleet of 57 reactors.

Should the EPR not be entered into the Grand Carénage maintenance budget, the investment of €51.4billion, as estimated by the French Court of Auditors (Cour des comptes), will therefore be distributed over 56 reactors, i.e. an average of €918m per reactor and additional operating expenses of roughly €309m, or €816k/MW and €275k/MW respectively.

The second component of the French energy transition law concerns nuclear generation: nuclear electricity generation must be limited to 50% of the energy mix by 2025. According to demand trends and the speed with which investments are made in renewables[24], we estimate that 14 to 20 reactors must be shut down.

The French Court of Auditors (Cour des comptes) estimates that the target set by the French law would result in the reduction of around one third of nuclear generation in France, i.e. the equivalent of electricity generation from 17 to 20 reactors[25].

In line with the law, we have used the assumption of a shutdown for 17 reactors, which reflects an average between the estimations of AlphaValue and the bottom range of the French Court of Auditors.

According to data disclosed by EDF, the Grand Carénage programme represents a recurring maintenance cost of approximately €3bn per year and additional investments of €1-2 billion per year (including ten-year inspections and periodical safety reviews).

In other words, maintenance expenditures for the period 2014-2025 may be estimated at approximately €33bn. Given the overall spending envelope of €51bn, additional investments can be estimated at €18.04bn (€1.64bn/year).

Based on the assumption of a shutdown of 17 reactors out of the 57 reactors in the French fleet (with the shutdown of the two reactors at Fessenheim and the commissioning of the EPR), the additional investment for the 40 operational reactors is estimated at €12.89 billion. The total cost for 40 reactors is €45.9 billion or €4.17 billion per year over the period from 2014 to 2025.

The amount of operating expenses estimated by the French Court of Auditors (Cour des comptes) must now be added to this figure, accounting for approximately €12.15 billion for 40 reactors.
The expenditure for the French nuclear power plant fleet is therefore estimated at €58.3 billion, or €5.3 billion per year.

[24] AlphaValue, EDF: "What a mess", (2015).
[25] Cour des comptes, Rapport publique thématique : *La maintenance des centrales nucléaires : une politique remise à niveau, des incertitudes à lever,* (2016) (in French).

The amount and schedule of the costs that EDF will have to finance for current and announced future investments are set out in the following table:

Table 6

€ billions	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
HPC & New Nuclear	1.00	1.00	2.25	2.25	2.25	2.25	2.25	2.25	2.25	2.25
EDF EN	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20
French grid	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35
Other (UK, Italy, Services)	3.70	3.70	3.70	3.70	3.70	3.70	3.70	3.70	3.70	3.70
GC	5.30	5.30	5.30	5.30	5.30	5.30	5.30	5.30	5.30	5.30
Total	**15.55**	**15.55**	**16.8**	**16.8**	**16.8**	**16.8**	**16.8**	**16.8**	**16.8**	**16.8**

Source: Alphavalue

For information, if no reactors are shut down (with the exception of Fessenheim), the additional investment would represent €18.04bn. Added to the €17.3bn in operating expenses and the €33bn in recurring maintenance expenditure over the period from 2014 to 2025, the overall cost of the Grand Carénage project would be €68.34bn, or €6.21bn/year.

It should be noted, however, that reactor renovation costs, together with a potential extension of their operating period, remain highly uncertain. It is currently difficult to define the scope of these operations. Moreover, given the almost total lack of feedback, the actual cost of these operations is difficult to estimate.
Some experts, such as Wise Paris, currently put forward costs ranging from €500m per reactor, in a context of insufficient safety, to more than €4bn in a context of safety conditions close to the requirements set for new reactors.
"These results confirm the risk to safety requirements arising from the profitability of any extensions and the need to clarify, prior to taking any decision, the economic stakes of these operations."[26]

C. How these operations are reflected in EDF's accounts

In order to cover the enormous cash deficit generated by its numerous investment projects, EDF has taken steps to optimise its cash-flow:

- The disposal of €10 billion in assets by 2020,
- Dividend distribution in shares for the 2016 and 2017 financial years,
- Capital increase project on financial markets to the tune of €4 billion,
- A plan to improve the working capital requirement with a target of optimising cash-flow over the 2015-2018 period by €1.8 billion, i.e. roughly €450 million per year.

[26] Wise Paris –*L'échéance de 40 ans pour le parc nucléaire français*- February 2014 (in French)

As regards post-2018 dividends, we have considered that EDF will have to reduce their amount. The group's net results will be hit directly by the increase in competition on its key markets, against the backdrop of a price environment in long-term depression.
As a result, we have adopted the assumption of an annual payment of €1.5bn but with a dividend distribution in shares (**with the dilutive effect related to the necessary capital increases over ten years**), i.e. 75% of the amount currently paid.

In addition, we have adopted the assumption of converting EBITDA into operating cash flow (FFO) of approximately 75% (following the payment of financial fees and taxes). This highly conservative assumption takes into account an improved working capital requirement.
The baseline scenario uses a low electricity price until 2018. After this time, the shutdown of the 17 reactors together with an increase in CO_2 emission prices (ETS) obtained through the various measures taken by the European Commission to stabilise emissions trading should lead to a recovery in electricity prices.
We have drawn up two scenarios for price trends after 2018 (Cal-18):

- A price development of +5% per year on the Cal-18 (€36/MWh), and
- a price development of approximately +10% per year.

These two scenarios will have different impacts on the FFO projected in coming years (*ceteris paribus* for the working capital requirement, taxes and financial fees).

As regards electricity demand, we take the prudent stance that it will be stable for the next few years. The expected increase in the number of electric vehicles in circulation will be, on hypothesis, offset by the improvement in energy efficiency.

Lastly, the decision to permanently shut down reactors, pursuant to the French energy transition law, would have a negative effect on EDF's results due to the reduction in the costs and products related to their operation. According to the studies of the French Court of Auditors (Cour des Comptes) on the cost of nuclear power[27], operating costs could be reduced by up to €3.9 billion per annum and the loss of revenue for EDF could reach roughly €5.7 billion per annum, i.e. an impact on the group's EBITDA of -€1.8 billion (with stable generation and prices).

In order to calculate the financial consequences of the shutdown of reactors as precisely as possible, it is necessary to have knowledge of the schedule up to 2025. As we do not have this information, we have adopted a theoretical assumption of shutdowns spread over time, closing as a priority the reactors reaching their fortieth anniversaries before 2025.

[27] Cour des comptes, Rapport publique thématique : *La maintenance des centrales nucléaires : une politique remise à niveau, des incertitudes à lever,* (2016). Le calcul est réalisé pour une production annuelle de 410 TWh.

Table 7 – Electricity prices +10% per annum after 2018 (50% nuclear power) in 2025 (17 reactors closed)

€ billions	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
FFO	**14.50**	**14.30**	**14.07**	**14.55**	**14.80**	**15.06**	**15.67**	**16.13**	**16.61**	**17.11**
Investment	15.55	15.55	16.80	16.80	16.80	16.80	16.80	16.80	16.80	16.80
HPC & New Nuclear	*1.00*	*1.00*	*2.25*	*2.25*	*2.25*	*2.25*	*2.25*	*2.25*	*2.25*	*2.25*
EDF EN	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20
French grid	*3.35*	*3.35*	*3.35*	*3.35*	*3.35*	*3.35*	*3.35*	*3.35*	*3.35*	*3.35*
Other (UK, Italy, Services)	*3.70*	*3.70*	*3.70*	*3.70*	*3.70*	*3.70*	*3.70*	*3.70*	*3.70*	*3.70*
GC	5.30	5.30	5.30	5.30	5.30	5.30	5.30	5.30	5.30	5.30
Dividends	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Asset disposal	2.00	2.00	2.00	2.00	2.00	0.00	0.00	0.00	0.00	0.00
Capital increase	0.00	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Change in net cash flow	**0.80**	**4.60**	**-0.88**	**-0.40**	**-0.15**	**-1.89**	**-1.28**	**-0.82**	**-0.34**	**0.16**

Source: Alphavalue

Table 8 – Electricity prices +5% per annum after 2018 with the 63.2GW capacity cap in 2025 (only 2 reactors closed)

€ billions	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
FFO	**14.50**	**14.30**	**14.07**	**14.27**	**14.23**	**14.19**	**14.48**	**14.60**	**14.73**	**14.87**
Investment	15.55	15.55	16.80	16.80	16.80	16.80	16.80	16.80	16.80	16.80
HPC & New Nuclear	*1.00*	*1.00*	*2.25*	*2.25*	*2.25*	*2.25*	*2.25*	*2.25*	*2.25*	*2.25*
EDF EN	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20
French grid	*3.35*	*3.35*	*3.35*	*3.35*	*3.35*	*3.35*	*3.35*	*3.35*	*3.35*	*3.35*
Other (UK, Italy, Services)	*3.70*	*3.70*	*3.70*	*3.70*	*3.70*	*3.70*	*3.70*	*3.70*	*3.70*	*3.70*
GC	5.30	5.30	5.30	5.30	5.30	5.30	5.30	5.30	5.30	5.30
Dividends	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Asset disposal	2.00	2.00	2.00	2.00	2.00	0.00	0.00	0.00	0.00	0.00
Capital increase	0.00	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	**0.80**	**4.60**	**-0.88**	**-0.68**	**-0.72**	**-2.76**	**-2.47**	**-2.35**	**-2.22**	**-2.08**

Source: Alphavalue

Based on these two price trend scenarios (of +5% to +10% per year), the impact on financial debt would be an additional €8.8 billion and €0.2 billion respectively for the 2016-2025 period.
The measures taken to optimise and control cash flow are proving to be positive in the short-term but problems arise after the asset disposal period and the start of work at Hinkley Point C.
According to the assumed price trend, the group's gross debt would be between €83.1 and €74.5 billion in 2025 (considering hybrid products as debt and not as equity).
EDF's debt ratio would therefore be around 300% as against 230% today.

The tables above consider the two components of the French energy transition law separately:

- The capping of capacity to 63.2GW. For this scenario, we have adopted an electricity price increase assumption of +5% per year. On the basis of stable nuclear capacity, the expected increase in the share of renewable electricity generated (in particular with the development of offshore wind power projects) will create a production overcapacity which will be partially offset by the expected increase in CO_2 prices after 2018.

- A decrease in nuclear electricity generation to 50% of the total energy mix. The reduction of installed nuclear capacity, through the shutdown of reactors, will result in an increase in electricity prices. We believe that the assumption of a 10% increase in electricity prices is consistent with this scenario.

According to these two scenarios, the increase in gross debt over the period from 2016 to 2025 will range from €0.2 billion (50% nuclear generation) to €8.8 billion (63.2GW cap).
Gross debt would be within the €74.5bn to €83.1bn bracket and FFO/gross debt around 20.5%. This ratio allows ratings agencies to assess a company's financial risks.

5. Overall financial impact

For a clearer view of the financial impact of our assumptions on EDF's accounts, we have drawn up a simplified version of the balance sheet, taking the two components of the French energy transition law into account separately.
Firstly, we considered a reduction in nuclear electricity generation to 50% of the total energy mix, together with a 10% price increase post-2018.
In a second table, we used the assumption of a 63.2GW ceiling applicable to nuclear capacity by 2025, together with a 5% price increase post-2018.
In addition, we considered demand to remain stable.
The balance sheets were calculated with and without the economies of scale expected from the decommissioning of reactors.

- Methodology

In order to draw up the 2025 balance sheet, we used the DCF (Discounted Cash Flow) method.
In applying this method, we were able to calculate the impact of price variations on FFO. The variation of the corresponding FFO can be used to determine changes in the company's cash flow and therefore its net financial debt ratio (with stable cash flows).
For macroeconomic values such as interest and inflation rates, we have used the European Central Bank's (ECB) targets for inflation and long-term interest rates. We added to this data that disclosed directly by EDF and have adopted an assumption of a 2% inflation rate, an

average discount rate of pension asset provisions of 2%, a return on dedicated assets of 6.0% and a discount rate for nuclear provisions of 4.5%.
As regards the discount rate, we have adopted the rate used by EDF even though we believe it to be too high in view of the sustained downward trend in sovereign interest rates used to calculate the regulatory ceiling of the discount rate for nuclear costs (French Decree dated 24 March 2015).

- **EDF's balance sheet excluding the economies of scale expected from reactor decommissioning**

Table 9 – Electricity prices +5% per annum after 2018 with a 63.2GW capacity ceiling

EDF's simplified balance sheet			
€ millions	2015	2015 Rev.	2025 (actuarial mark-to-market)
Assets			
Total intangible assets	19 125	19 125	16 720
Tangible assets	130 314	130 314	166 520
Working capital requirement	11 413	11 413	13 213
Dedicated assets	*23 480*	*23 480*	*39 669*
Financial assets	55 641	55 641	65 528
Other current assets	2 720	2 720	3 157
Total assets (net of ST obligations)	*219 213*	*219 213*	*265 137*
Equity	24 661	- 28 139	-28 075
Minority interests	5 491	5 491	6 500
Liabilities			
Nuclear provisions	46 809	99 609	119 042
Decommissioning provisions (FR)	*17 485*	*36 685*	*43 842*
Waste provisions (FR)	*18 645*	*52 245*	*62 438*
Provisions (UK & Belgium)	*10 679*	*10 679*	*12 762*
Other provisions*	51 056	51 056	62 064
Pension provisions	22 544	22 544	26 942
Net debt**	59 404	59 404	68 164
Other expenses	9 248	9 248	10 500
Total liabilities	*189 061*	*241 861*	*286 712*

*Includes the specific liabilities of French public electricity distribution concessions
** With stable cash flows

Table 10 – Electricity prices +10% per annum after 2018 (50% nuclear generation)

EDF's simplified balance sheet			
€ millions	**2015**	**2015 Rev.**	**2025 (actuarial mark-to-market)**
Assets			
Total intangible assets	19 125	19 125	16 720
Tangible assets	130 314	130 314	166 520
Working capital requirements	11 413	11 413	13 213
Dedicated assets	*23 480*	*23 480*	*39 669*
Financial assets	55 641	55 641	65 528
Other current assets	2 720	2 720	3 157
Total assets (net of ST obligations)	*219 213*	*219 213*	*265 137*
Equity	**24 661**	**-29 839**	**-20 347**
Minority interests	5 491	5 491	5 500
Liabilities			
Nuclear provisions	46 809	101 309	121 074
Decommissioning provisions (FR)	*17 485*	*38 385*	*45 874*
Waste provisions (FR)	*18 645*	*52 245*	*62 438*
Provisions (UK)	*10 679*	*10 679*	*12 762*
Other provisions*	51 056	51 056	62 064
Pension provisions	22 544	22 544	26 942
Net debt**	59 404	59 404	59 404
Other expenses	9 248	9 248	10 500
Total liabilities	*189 061*	*243 561*	*279 984*

* Includes the specific liabilities of French public electricity distribution concessions

** With stable cash flows

- **EDF's balance sheet including the economies of scale expected from reactor decommissioning**

Table 11 – Electricity prices +5% per annum after 2018 with a 63.2GW capacity ceiling

EDF's simplified balance sheet			
€ millions	**2015**	**2015 Rev.**	**2025 (actuarial mark-to-market)**
Assets			
Total intangible assets	**19 125**	**19 125**	**16 720**
Tangible assets	**130 314**	**130 314**	**166 520**
Working capital requirement	**11 413**	**11 413**	**13 213**
Dedicated assets	***23 480***	***23 480***	***39 669***
Financial assets	**55 641**	**55 641**	**65 528**
Other current assets	**2 720**	**2 720**	**3 157**
Total assets (net of ST obligations)	***219 213***	***219 213***	***265 137***
Equity	**24 661**	**- 24 739**	**-24 012**
Minority interests	**5 491**	**5 491**	**6 500**
Liabilities			
Nuclear provisions	**46 809**	**96 209**	**114 979**
Decommissioning provisions (FR)	***17 485***	***33 285***	***39 779***
Waste provisions (FR)	***18 645***	***52 245***	***62 438***
Provisions (UK & Belgium)	***10 679***	***10 679***	***12 762***
Other provisions*	**51 056**	**51 056**	**62 064**
Pension provisions	**22 544**	**22 544**	**26 942**
Net debt**	**59 404**	**59 404**	**68 164**
Other expenses	**9 248**	**9 248**	**10 500**
Total liabilities	***189 061***	***238 461***	***282 649***

* Includes the specific liabilities of French public electricity distribution concessions

** With stable cash flows

Table 12 – Electricity prices +10% per annum after 2018 (50% nuclear generation)

EDF's simplified balance sheet			
€ millions	**2015**	**2015 Rev.**	**2025 (actuarial mark-to-market)**
Assets			
Total intangible assets	19 125	19 125	16 720
Tangible assets	130 314	130 314	166 520
Working capital requirement	11 413	11 413	13 213
Dedicated assets	*23 480*	*23 480*	*39 669*
Financial assets	55 641	55 641	65 528
Other current assets	2 720	2 720	3 157
Total assets (net of ST obligations)	*219 213*	*219 213*	*265 137*
Equity	**24 661**	**-26 139**	**-15 925**
Minority interests	5 491	5 491	5 500
Liabilities			
Nuclear provisions	46 809	97 609	116 652
Decommissioning provisions (FR)	*17 485*	*34 685*	*41 452*
Waste provisions (FR)	*18 645*	*52 245*	*62 438*
Provisions (UK)	*10 679*	*10 679*	*12 762*
Other provisions*	51 056	51 056	62 064
Pension provisions	22 544	22 544	26 942
Net debt**	59 404	59 404	59 404
Other expenses	9 248	9 248	10 500
Total liabilities	*189 061*	*239 861*	*275 563*

* Includes the specific liabilities of French public electricity distribution concessions
** With stable cash flows

By analysing the results of the changes to EDF's economic model by 2025 and the impact of the various scenarios related to the French energy transition law, we can conclude that from a financial standpoint, EDF will benefit from a long-term reduction in its installed nuclear capacity.

By reducing its installed capacity, the increase in electricity prices, caused by the reduction of overcapacity, will have a positive effect by 2025 on its turnover, which will be greater than the losses caused by the decrease in its volumes. EDF will no longer be a net electricity exporter with its neighbouring countries (UK, Germany, Italy, Belgium, Spain) and will thereby generate swift price increases at times of supply security tensions in Europe due to periods of low renewable energy generation or lower-than-average winters.

The permanent shutdown of reactors, together with an increase in carbon prices (ETS), will improve operating units' profitability. This optimised profitability of operating units will result in a recovery of cash flow (FFO) and a positive change in cash flow, together with a lower increase in debt ratios by 2025.

This scenario has been recently confirmed with the shutdown of several reactors (approximately 20 out of the 58 in operation) due to maintenance and component inspections required by ASN. This situation, which raises concerns of supply issues in the short-term, has led to a significant increase in spot prices.
Growth in the investments in renewables over the next ten years, as provided for by the French energy transition law, will result in a significant increase in installed capacity in France and thereby mitigate supply security risks.

In conclusion, the shutdown of 17 reactors by 2025 would:

- Support electricity prices in the medium-term,
- Increase the profitability of EDF's generation assets in operation
- Comply with the two components of the French energy transition law on nuclear power.

Currently, EDF's main concern is its inability to meet its obligations to finance reactor decommissioning and waste management costs.
According to our different scenarios, total underfunding is assessed to be between €57.3 and €63.4bn in 2025.

Regardless of the scenario adopted, an adjustment of nuclear provisions (and the corresponding dedicated assets), would result in EDF's bankruptcy from an accounting perspective.

Appendix: Operation timeframes adopted for EDF's French reactors in operation

Reactor name	Design	Net power (MWe)	Commercial commissioning	Projected number of years of operation	Projected / actual shutdown date	Number of years of operation completed	Remaining number of years of operation
FESSENHEIM-1	CP0	880	1978	40	2018	38	2
FESSENHEIM-2	CP0	880	1978	40	2018	38	2
BUGEY-2	CP0	910	1979	50	2029	37	13
BUGEY-3	CP0	910	1979	50	2029	37	13
BUGEY-4	CP0	880	1979	40	2019	37	3
BUGEY-5	CP0	880	1980	50	2030	36	14
DAMPIERRE-17	CP1	890	1980	50	2030	36	14
GRAVELINES-17	CP1	910	1980	40	2020	36	4
GRAVELINES-27	CP1	910	1980	40	2020	36	4
TRICASTIN-17	CP1	915	1980	40	2020	36	4
TRICASTIN-27	CP1	915	1980	40	2020	36	4
BLAYAIS-17	CP1	910	1981	50	2031	35	15
DAMPIERRE-27	CP1	890	1981	50	2031	35	15
DAMPIERRE-37	CP1	890	1981	50	2031	35	15
DAMPIERRE-47	CP1	890	1981	50	2031	35	15
GRAVELINES-37	CP1	910	1981	40	2021	35	5
GRAVELINES-47	CP1	910	1981	40	2021	35	5
TRICASTIN-37	CP1	915	1981	40	2021	35	5
TRICASTIN-47	CP1	915	1981	40	2021	35	5
BLAYAIS-27	CP1	910	1983	50	2033	33	17
BLAYAIS-3	CP1	910	1983	50	2033	33	17
BLAYAIS-4	CP1	910	1983	50	2033	33	17
ST. LAURENT-B-17	CP2	915	1983	40	2023	33	7
ST. LAURENT-B-27	CP2	915	1983	40	2023	33	7
CHINON-B-17	CP2	905	1984	40	2024	32	8
CHINON-B-27	CP2	905	1984	40	2024	32	8
CRUAS-1	CP2	915	1984	50	2034	32	18
CRUAS-3	CP2	915	1984	50	2034	32	18

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CRUAS-2	CP2	915	1985	50	2035	31	19
CRUAS-4	CP2	915	1985	50	2035	31	19
GRAVELINES-5	CP1	910	1985	40	2025	31	9
GRAVELINES-6	CP1	910	1985	40	2025	31	9
PALUEL-1	P4	1330	1985	40	2025	31	9
PALUEL-2	P4	1330	1985	40	2025	31	9
FLAMANVILLE-1	P4	1330	1986	40	2026	30	10
PALUEL-3	P4	1330	1986	40	2026	30	10
PALUEL-4	P4	1330	1986	40	2026	30	10
ST. ALBAN-1	P4	1335	1986	40	2026	30	10
CATTENOM-1	P'4	1300	1987	40	2027	29	11
CHINON-B-37	CP2	905	1987	50	2037	29	21
FLAMANVILLE-2	P4	1330	1987	40	2027	29	11
ST. ALBAN-2	P4	1335	1987	40	2027	29	11
BELLEVILLE-1	P'4	1310	1988	40	2028	28	12
CATTENOM-2	P'4	1300	1988	40	2028	28	12
CHINON-B-47	CP2	905	1988	50	2038	28	22
NOGENT-1	P'4	1310	1988	40	2028	28	12
BELLEVILLE-2	P'4	1310	1989	40	2029	27	13
NOGENT-2	P'4	1310	1989	40	2029	27	13
PENLY-1	P'4	1330	1990	40	2030	26	14
CATTENOM-3	P'4	1300	1991	40	2031	25	15
GOLFECH-1	P'4	1310	1991	40	2031	25	15
CATTENOM-4	P'4	1300	1992	40	2032	24	16
PENLY-2	P'4	1330	1992	40	2032	24	16
GOLFECH-2	P'4	1310	1994	40	2034	22	18
CHOOZ-B-1	N4	1500	2000	40	2040	16	24
CHOOZ-B-2	N4	1500	2000	40	2040	16	24
CIVAUX-1	N4	1495	2002	40	2042	14	26
CIVAUX-2	N4	1495	2002	40	2042	14	26

900MW reactors extended in accounting terms by EDF

900MW reactors set to be shut down in compliance with the French energy transition law (Alphavalue assumption).